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RAPID CRACK PROPAGATION AND ARREST IN POLYMERS.(U)
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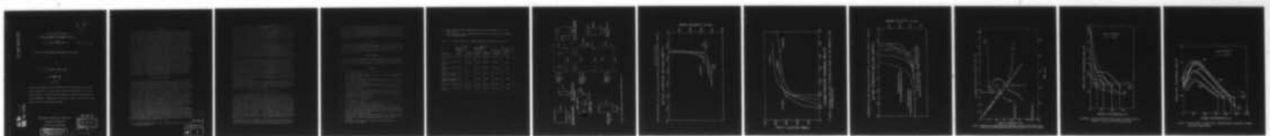

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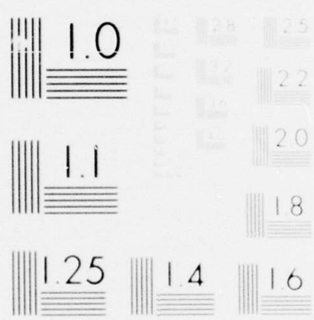

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6 RAPID CRACK PROPAGATION AND ARREST IN POLYMERS.

by

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12 16p.

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INTRODUCTION

As a result of concerted research efforts of the past two decades, many of the basic problems in linear fracture mechanics have been resolved with the gradual acceptance of fracture mechanics as a design tool in industry. Although linear fracture mechanics can be used effectively in preventing much of the predicted fracture modes, there are limited occasions when fracture cannot be avoided due to unusual loading conditions which may or may not occur during the lifetime of a structure. As a secondary safety measure, a crack arrest mechanism which could prevent catastrophic failures of critical structural components are thus required in some designs. Since the design of a crack arrest mechanism requires knowledge of fracture dynamics, increasing research efforts are being expended in studying the basic laws which govern rapid crack propagation and crack arrest. Progress in fracture dynamics, however, is hampered by the lack of comparable theoretical and experimental tools which contributed to the rapid progress made in linear fracture mechanics.

Following the pioneering paper of Wells and Post[1], three groups of researchers[2-8] have used either dynamic photoelastic technique or dynamic caustics* to determine experimentally the dynamic state of stress surrounding a propagating crack tip in various birefringent polymers. These optical techniques can be used to determine within reasonable accuracy the dynamic stress intensity factor of a rapidly running or arresting crack. No comparable experimental technique exists for measuring the dynamic stress intensity factor in a fracturing metal plate. As a result, considerable data on the fracture dynamic properties of birefringent polymers have been generated for the purpose of providing insights into the dynamic fracture toughness, K_{ID}, and crack arrest stress intensity factor, K_{Ia}, of metals. In the following a review and comparison of published fracture dynamic properties of four birefringent polymers, a polyester resin Homalite-100, epoxy resin Araldite B, modified epoxy resin and polycarbonate, are given.

DYNAMIC FRACTURE TOUGHNESS

Dynamic fracture toughness, K_{ID}, is the dynamic counterpart of the static fracture toughness, K_{IC}, and is equal to the measured dynamic stress intensity factor, K_I^{dyn}, in a fracturing material. Considerable direct[6-8] and indirect[10,12] evidence showing unique relations between K_{ID} and crack velocity, $\dot{a}$, for the above polymers and some metals have been generated to date. The K_{ID} versus $\dot{a}$ relations of birefringent polymers were established through the use of various fracture specimens, such as those shown in Figure 1. For these polymeric fracture specimens, one notes considerable differences in specimen sizes in contrast to the small differences between the respective dilatational wave velocities shown in Table 1. Thus the transit time for a dynamic event to reach a moving crack tip would be predominantly governed by the specimen size, which could result in differences in dynamic responses of specimens of similar configuration but different sizes. The extent of dynamic interaction with the crack velocity and possibly with the postulated material property of K_{ID} is not clear at this time but it is generally understood that smaller fracture specimens will accentuate the dynamic effects.[12]

Using dynamic photoelasticity, T. Kobayashi and his colleagues[6,7] determined K_{ID} in a variety of single-edged notch (SEN) specimens, wedge-loaded double cantilever beam (DCB) specimens and wedge-loaded contoured DCB (C-DCB) specimens machined from 12.7mm thick Homalite-100 plates as shown in Figure 2. Figure 3 shows the K_{ID} determined by the authors for similar SEN and smaller DCB specimens machined from thinner Homalite-100 plates. Other than the large data scatter[5], which is not evident in Figure 3, the authors' K_{ID} versus $\dot{a}$ relations and those of T. Kobayashi et al. for different Homalite-100 plates are in reasonable agreement under static loading.

* For a more detailed explanation of the lesser known method of caustics, see for example Reference 9.

Figure 3 also shows the same 9.5mm thick Homalite-100 plate tested under the impact loading of dynamic tear testing (DTT)[2,5]. Although data scatters are considerably larger in the DTT results, the averaged K_{ID} as shown in Figure 3 is substantially lower than the corresponding K_{ID} in statically loaded specimens at lower crack velocities. The lower K_{ID} at lower $\dot{a}$ is obtained when the crack propagates into the region closer to the impact zone which is still in compression under highly dynamic loading condition which probably does not exist in static loading of other specimens shown in Figure 1. This change in minimum K_{ID} under dynamic loading could cast doubt on the validity of using the minimum dynamic fracture toughness, K_{Im}, as a conservative estimate of a fracture criterion.[13]

Figure 4 shows the K_{ID} versus $\dot{a}$ curves for Araldite-B[8], two modified epoxies[7] and polycarbonate[5]. The static fracture toughness of these polymers varied from somewhat tough to extremely tough material in comparison to the brittle Homalite-100 plates and are thus grouped separately in this figure. It is interesting to note that the spread in the bifurcated K_{ID} versus $\dot{a}$ curves for the tougher, modified epoxies is approximately equal to the scatter band in Araldite B and polycarbonate specimens. Also note that the slant in K_{ID} versus $\dot{a}$ curves of the DDT specimens in Figures 3 and 4 suggest again that the minimum K_{ID} at lower $\dot{a}$ could be significantly altered under dynamic loading.

Since the dynamic effect in a finite size fracture specimen is governed by its loading conditions, such effect could be detected in statically loaded fracture specimens if the crack initiation stress intensity factor, K_{IQ}, is extremely high. Figure 5 shows the K_{ID} versus $\dot{a}$ curves for two different wedge-loaded DCB specimens[3,7] machined from different Homalite-100 plates. As shown in Figure 1, the two DCB specimens differed by more than a factor of 2 in linear dimensions but both specimens were loaded at a high K_{IQ} of more than twice the K_{IC} values, thus causing the crack to run through the entire specimen height without arresting. Despite the difference in sizes, both K_{ID} versus crack extension relations, and more so the $\dot{a}$ versus crack extension relations, were very similar thus indicating that the stress wave effects generated by a crack propagating at the same $\dot{a}$ will be similar but its influence on K_{ID} will vary with the transit time of the stress wave returning to the propagating crack tip.

The above results show that K_{ID} is influenced by stress wave effects and that K_{ID} at lower $\dot{a}$ could be altered significantly under dynamic loading. In the absence of significant dynamic effects, however, a unique K_{ID} versus $\dot{a}$ relation of the Γ shape appears to adequately characterize the dynamic fracture response of these birefringent polymers.

CRACK ARREST STRESS INTENSITY FACTOR

The results of Figure 2 and much of Figure 3 have led Irwin[13] and others[6,7,15] to postulate the use of minimum dynamic fracture toughness, K_{Im}, as a conservative estimate of a crack arrest stress intensity factor, K_{Ia}. In addition, Kalthoff et al.[8] have shown that this K_{Im} is indeed a material property as shown in Figure 6 by the constant K_{Ia}^{dyn} observed in six wedge-loaded DCB specimens machined from Araldite B plates. Noting that the existence of such K_{Ia}^{dyn} could be a characteristic response of the particular specimen geometry, the authors replotted some previously published crack arrest data[14] in Figure 7 following the format of Kalthoff et al. For the four SEN specimens with a geometry shown in Figure 1, not only did a constant K_{Ia}^{dyn} similar to the Kalthoff data exist but also the corresponding static stress intensity factor after crack arrest, K_{Ia}^{stat}, varied with the total crack length at arrest as shown by Kalthoff et al[8]. This variation in K_{Ia}^{stat} refutes the contention of some that crack arrest can be characterized by a material property which is the static stress intensity factor a few milliseconds after crack arrest[13,15].

The differences between K_{ID}^{dyn} obtained for the larger SEN specimen in Figures 7 and the lower K_{Im} observed in the smaller DCB specimens in Figure 3, needless to mention the noticeable difference in K_{Im} obtained from the DTT specimens, leads one to speculate again that dynamic effects may significantly alter the observed K_{Im} in different specimens. Despite the high K_{IQ} (varied from one and one-half to four times the K_{Ic}) in Kalthoff's wedge-loaded DCB specimens, the tougher Araldite B material seemed to attenuate the stress wave effects more than in brittle Homalite-100 wedge-loaded DCB specimens of similar size[7]. As a result, the apparent existence of a K_{Im} would be more noticeable in the Araldite B specimens loaded under fixed wedge-displacement condition[8].

CONCLUSION

There is mounting evidence supporting the existence of a unique K_{ID} versus $\dot{a}$ relation which was derived from fracture dynamic experiments using large polymeric specimen subjected to static loading. The existence of such unique K_{ID} versus $\dot{a}$ relation and hence the validity of a K_{Im} as a conservative estimate of the crack arrest stress intensity factor under dynamic loading, however, remain unresolved.

ACKNOWLEDGEMENT

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REFERENCES

1. A.A. Wells and D. Post, *Proc. of Society for Experimental Stress Analysis, 16*, 69 (1958).
2. A.S. Kobayashi and C.F. Chan, *Experimental Mechanics, 16*, 176 (May 1976).
3. A.S. Kobayashi, S. Mall and M.H. Lee, *Cracks and Fracture*, ASTM STP 601, 274 (June 1976).
4. A.S. Kobayashi, B.G. Wade and W.B. Bradley, *Deformation and Fracture of High Polymers*, H.H. Kausch, J.A. Hassell and R.I. Jaffee, Ed., Plenum Press, New York, 487 (1973).
5. S. Mall, "A Numerical-Experimental Investigation of Dynamic Fracture", a Ph.D. dissertation submitted to University of Washington (1977).
6. T. Kobayashi and J.W. Dally, *Fast Fracture and Crack Arrest*, ASTM STP 627, 257 (July 1977).
7. G.R. Irwin, J.W. Dally, T. Kobayashi, W.L. Fourney and J.M. Etheridge, "A Photoelastic Characterization of Dynamic Fracture", University of Maryland Report prepared for the U.S. Nuclear Regulatory Commission, NUREG-0072, NRC-5, December 1976.
8. J. Kalthoff, J. Beinert and S. Winkler, *Fast Fracture and Crack Arrest*, ASTM STP 627, 161 (July 1977).
9. P.S. Theocaris, *J. of Applied Mechanics, Trans. of ASME, 37*, Series E, No. 2, 409 (June 1970).
10. R.G. Hoagland, P.C. Gehlen, A.R. Rosenfield and G.T. Hahn, *Fast Fracture and Crack Arrest*, ASTM STP 627, 203 (July 1977).
11. G.T. Hahn, P.C. Gehlen, R.G. Hoagland, C.W. Marschall, M.F. Kanninen, C. Popelar and A.R. Rosenfield, "Critical Experiments, Measurements and Analyses to Establish a Crack Arrest Methodology for Nuclear Pressure Vessel Steels", Task 62, Second Annual Report, Battelle Columbus Laboratories BMI-1959 (October 1976).
12. M.F. Kanninen, E. Mills, G.T. Hahn, C.W. Marschall, D. Corek, A. Coyle, K. Masubushi, K. Itoga, "A Study of Ship Hull Crack Arrest Systems", Project SR-226, Battelle Columbus Laboratories Report (December 18, 1977).
13. G.R. Irwin, *Dynamic Fracture Toughness*, The Welding Institute, Cambridge, 1 (July 1976).

14. W.B. Bradley and A.S. Kobayashi, *Engrg. Fracture Mechanics, 3,* 317 (June 1971).
15. R.P. Crosley and E.J. Ripling, *Fast Fracture and Crack Arrest,* ASTM STP 627, 203 (July 1977).

Table 1. Elastic Properties of Model Materials for Fracture Specimens

Material	Static		Dynamic		Fracture Toughness MPa$\sqrt{m}$	Dilatational Wave Velocity m/sec
	Modulus of Elasticity GPa	Poisson's Ratio	Modulus of Elasticity GPa	Poisson's Ratio		
Homalite-100 [2-4]	3.72	0.345	4.65	0.345	0.650	2400
Homalite-100 [5]	3.72	0.36	4.80	0.36	0.415	2590
Homalite-100 [6,7]	3.86	-	4.82	0.31	0.450	2150
Modified Epoxy Blend No.3[7]	3.01	-	3.95	0.34	1.180	1970
Modified Epoxy Blend No.12[7]	3.97	-	4.07	0.37	0.910	2020
Araldite B [8]	3.38	0.33	3.66	0.39	0.790	2500
Polycarbonate [5]	2.38	0.36	2.72	0.36	3.340	1960

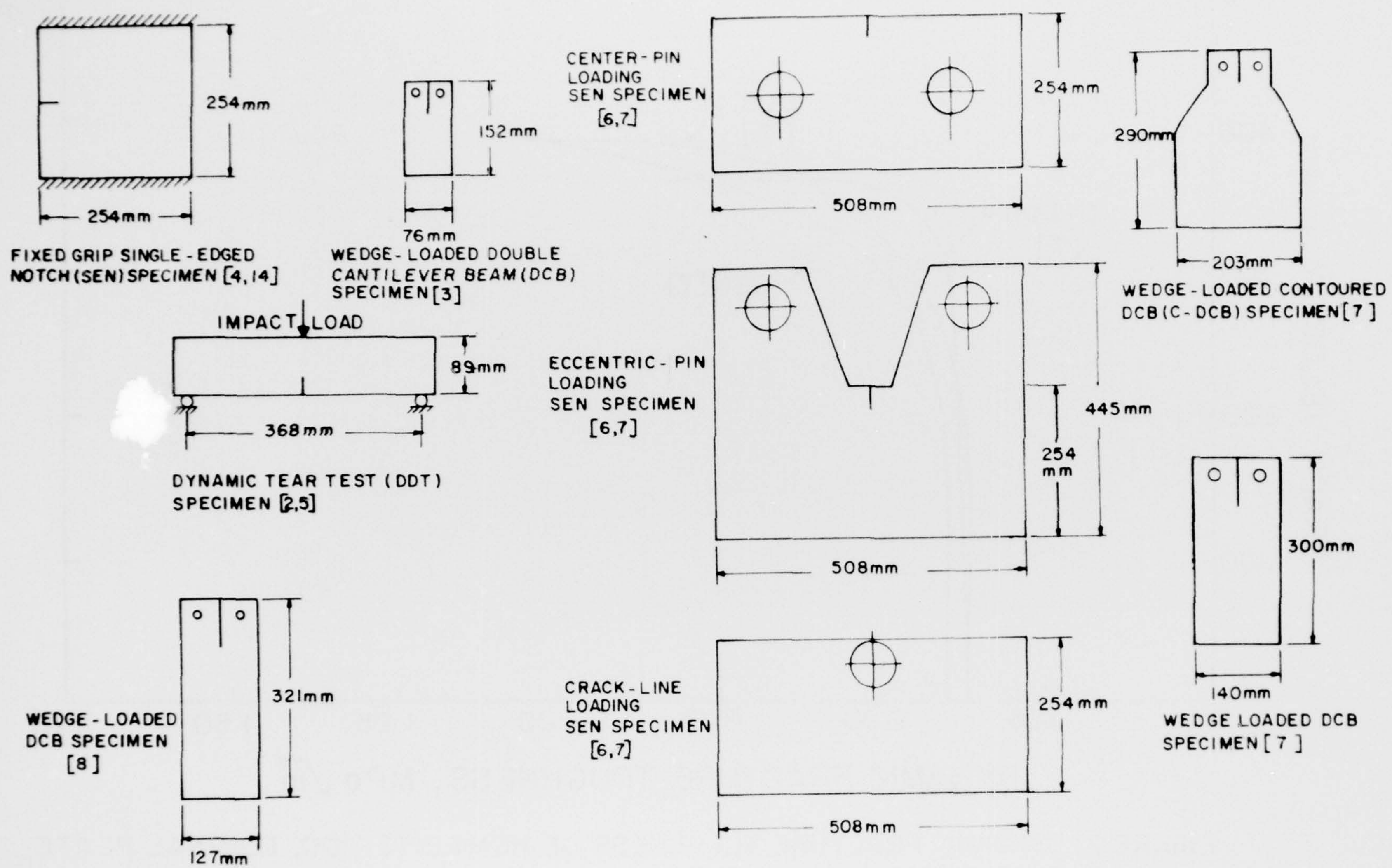

FIGURE 1. SPECIMENS USED IN FRACTURE DYNAMIC ANALYSIS

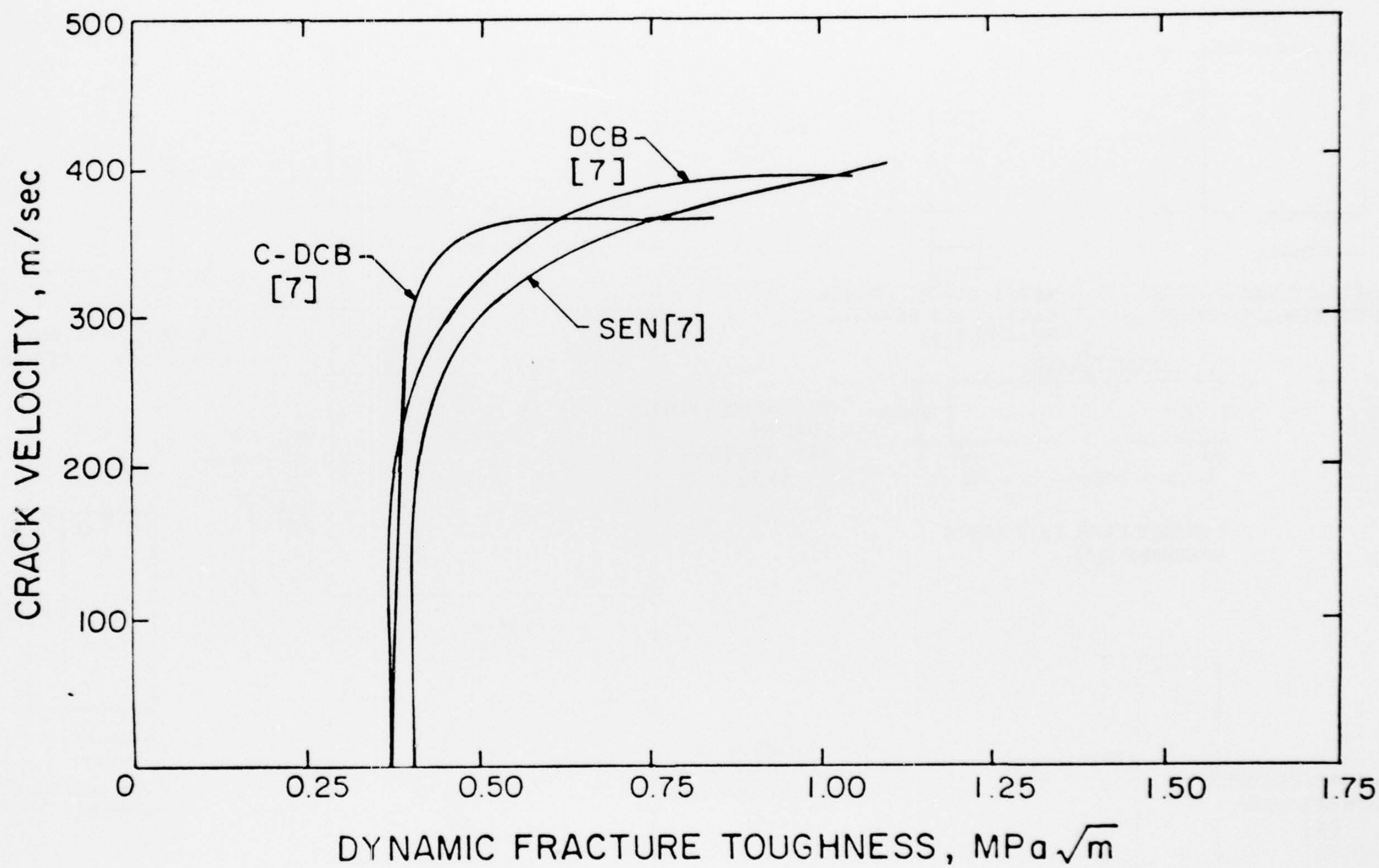

FIGURE 2. DYNAMIC FRACTURE TOUGHNESS OF HOMALITE-100, NOMINAL PLATE THICKNESS 12.7 mm.

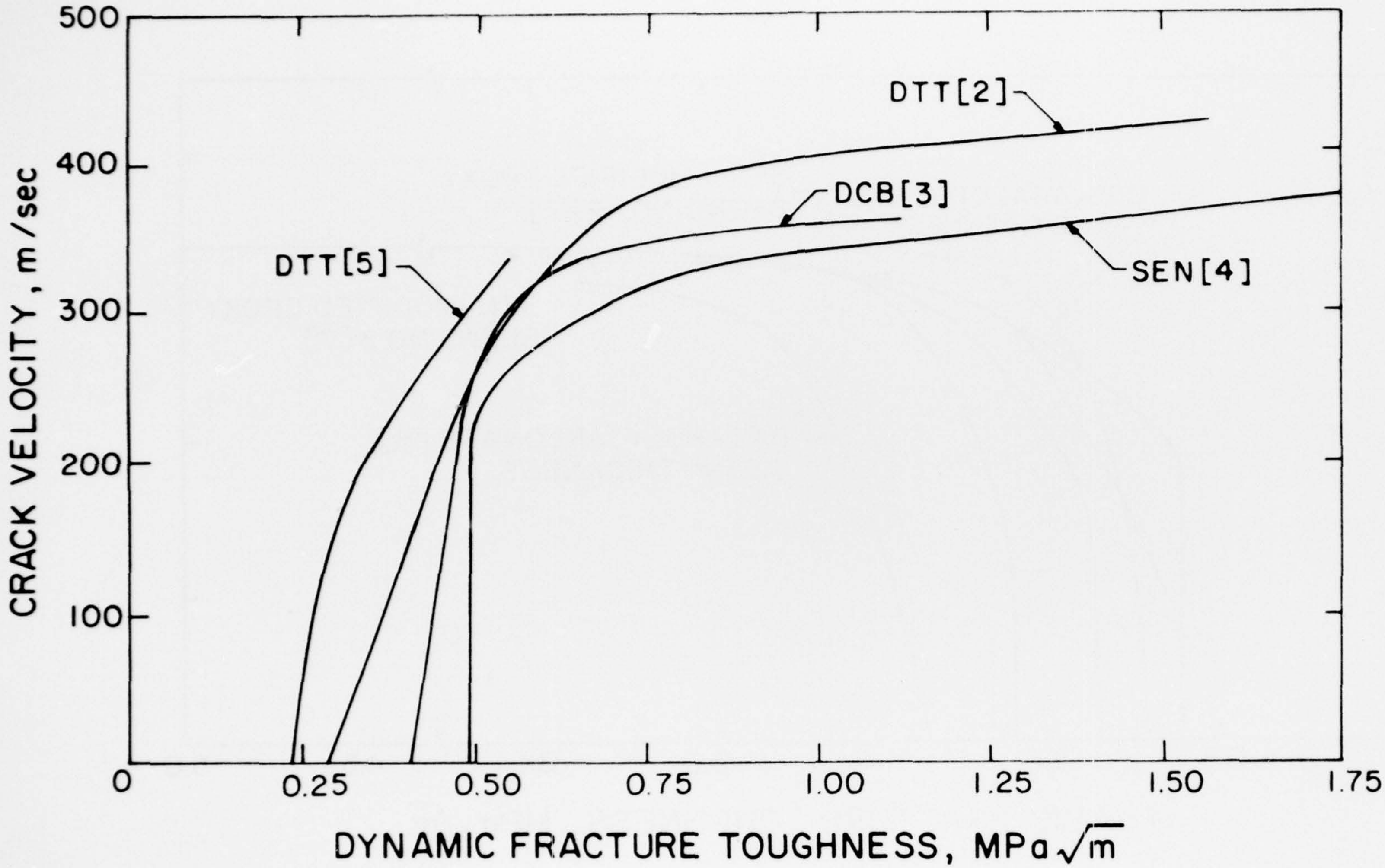

FIGURE 3. DYNAMIC FRACTURE TOUGHNESS OF HOMALITE-100, NOMINAL PLATE THICKNESS 9.5 mm.

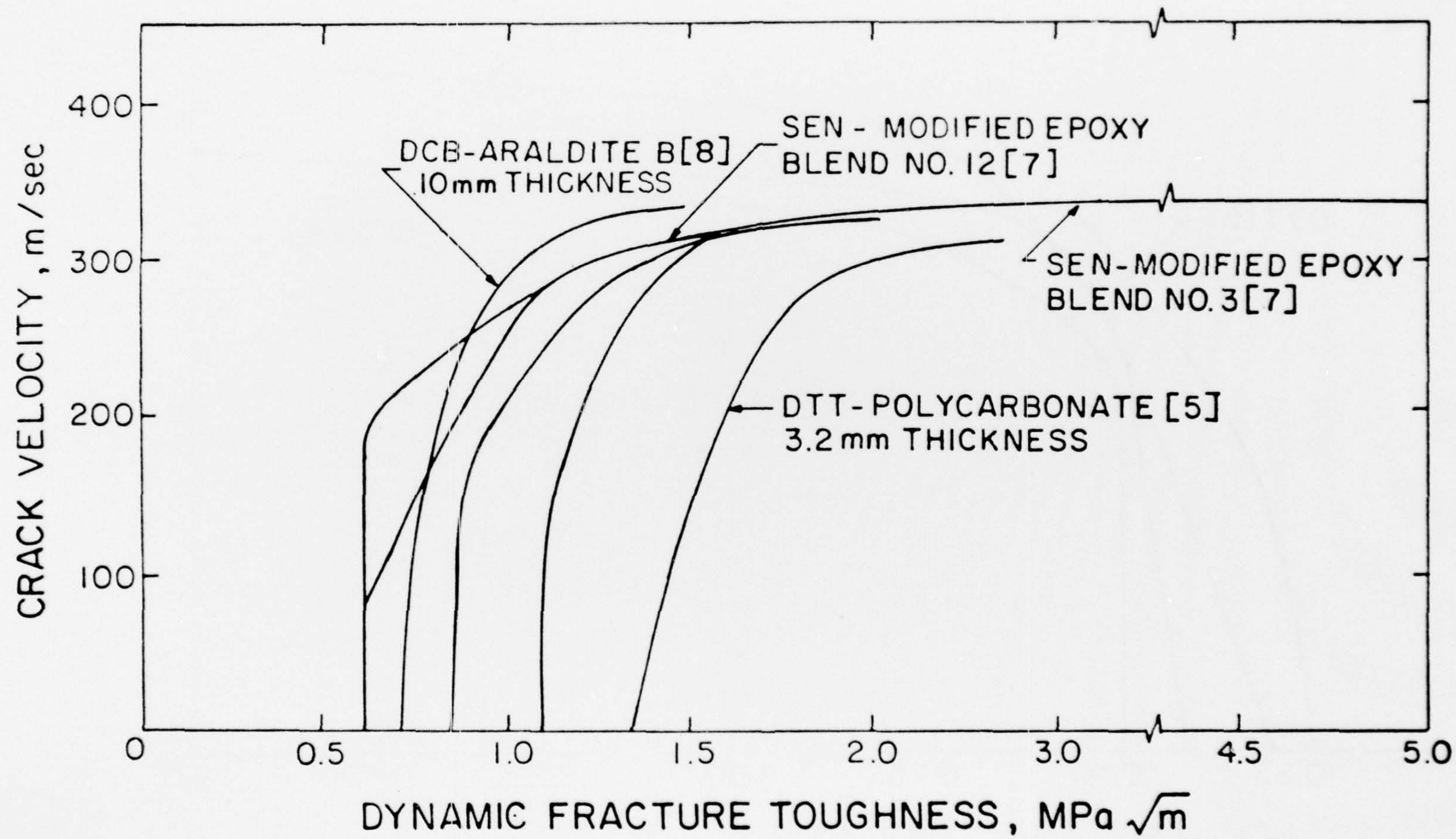

FIGURE 4. DYNAMIC FRACTURE TOUGHNESS OF EPOXIES AND POLYCARBONATE

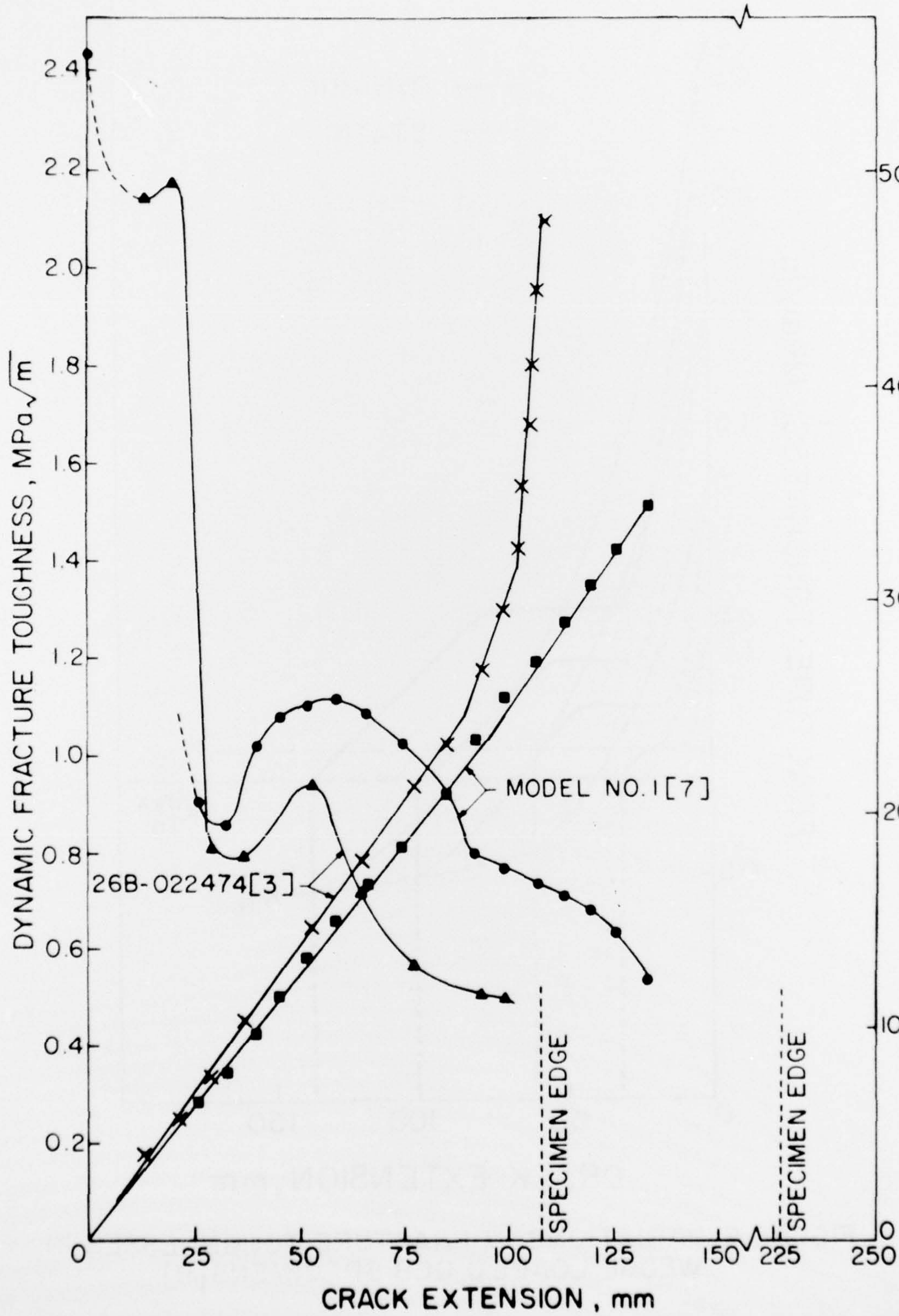

FIGURE 5. VARIATION OF DYNAMIC FRACTURE TOUGHNESS AND CRACK EXTENSION VERSUS TIME RELATION IN TWO WEDGE-LOADED DCB SPECIMENS WITHOUT CRACK ARREST.

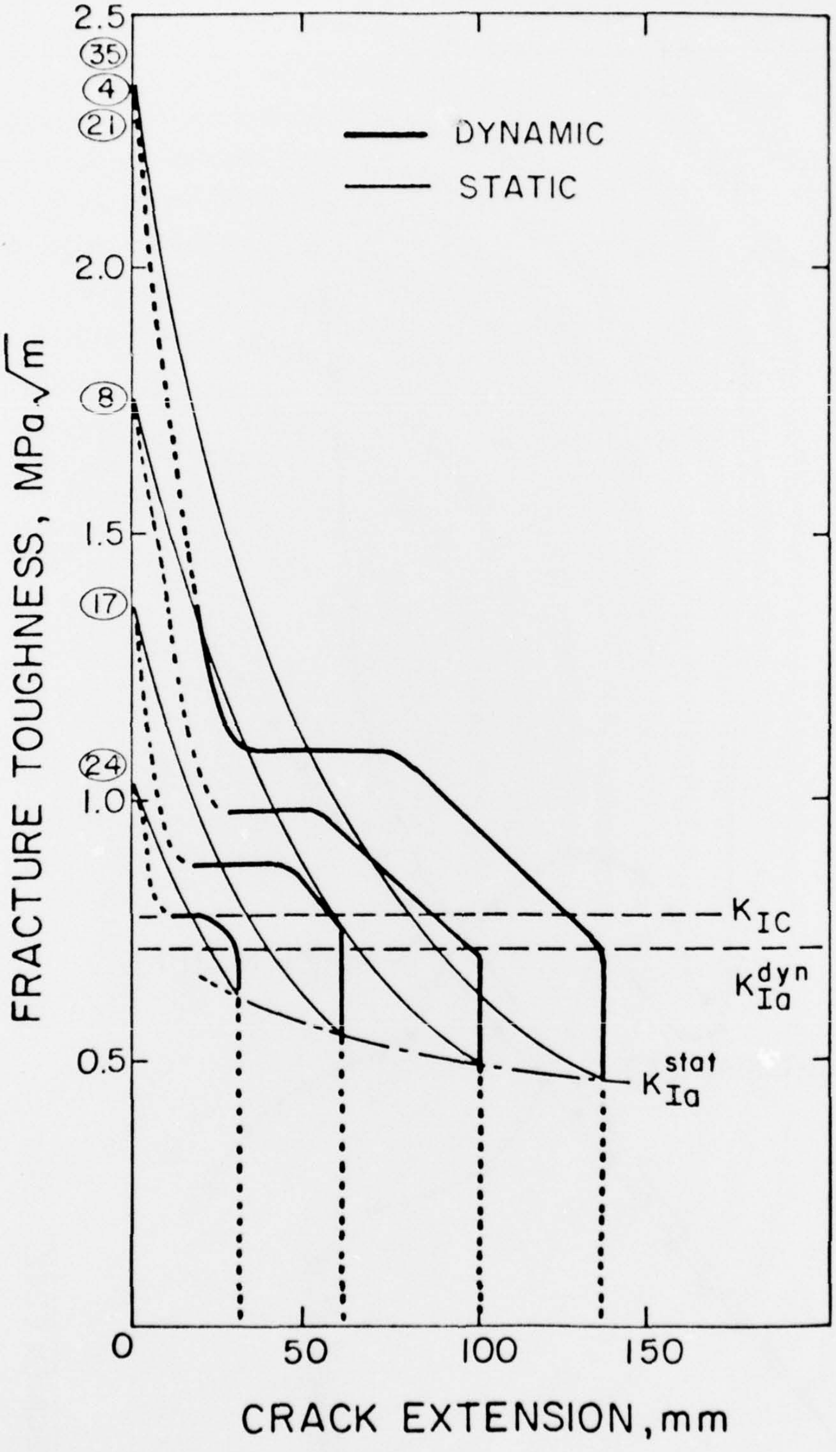

FIGURE 6. VARIATIONS IN FRACTURE TOUGHNESSES IN WEDGE-LOADED DCB SPECIMENS[8]

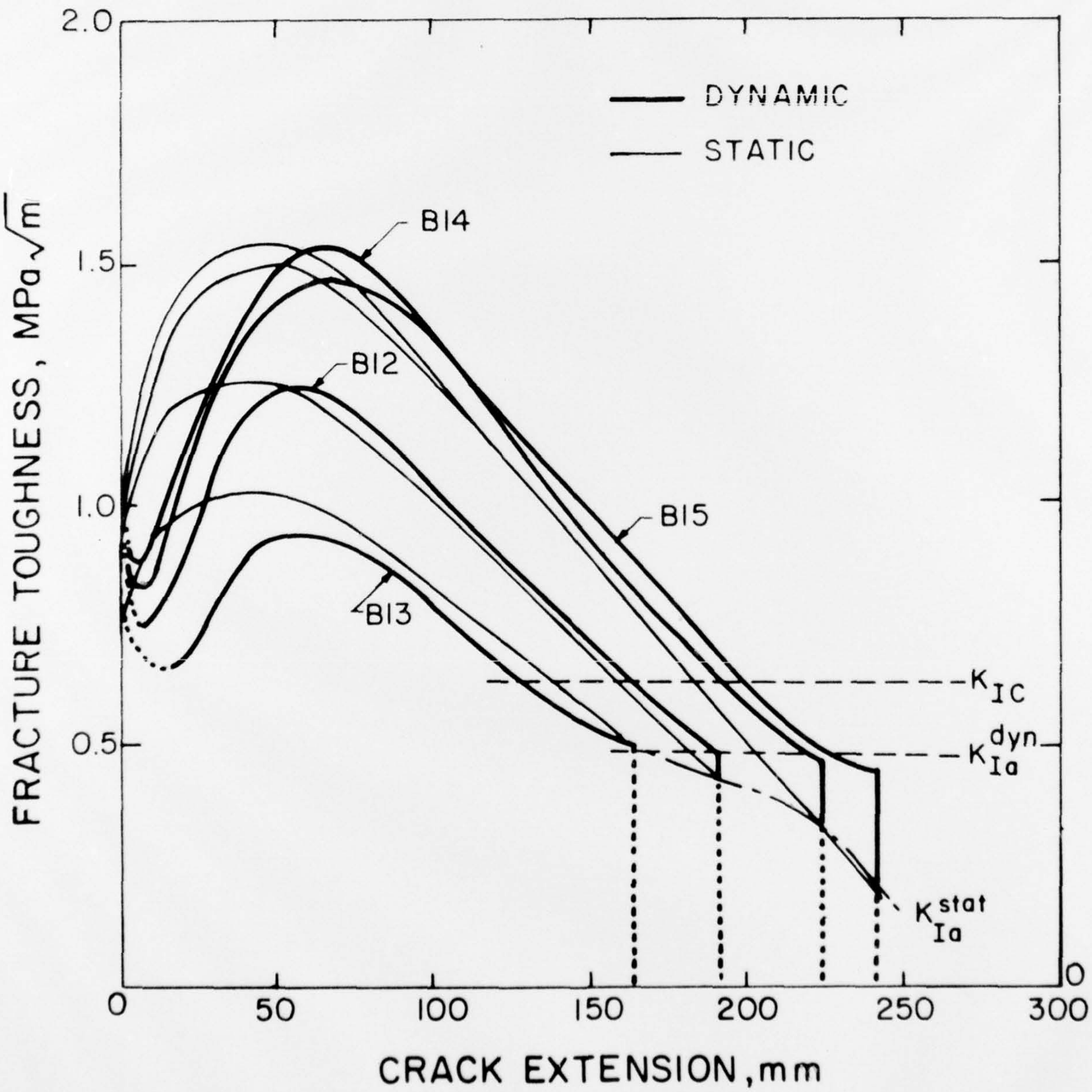

FIGURE 7. VARIATIONS IN FRACTURE TOUGHNESSES IN WEDGE-LOADED DCB SPECIMENS [14]

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Published fracture dynamic properties of four birefringent polymers, i.e. polyester resin Homalite-100, epoxy resin Araldite B, modified epoxy resins and polycarbonate, determined by dynamic photoelasticity and dynamic caustics are reviewed. Despite mounting evidence of unique dynamic fracture toughness, K_{ID}, versus crack velocity, $\dot{a}$, relations of these polymers fractured under static loading, such relations could not be duplicated in fracture specimens loaded dynamically. The existence of unique K_{ID} versus $\dot{a}$ relations and the

(continued on reverse)

(Continued) validity of a minimum dynamic fracture toughness, K_{Im}, as a conservative estimate of the crack arrest stress intensity factor for polymers subjected to dynamic loading remains in doubt.